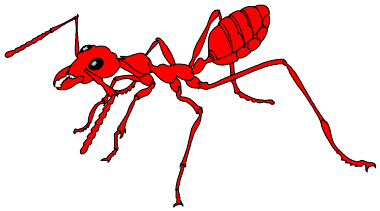


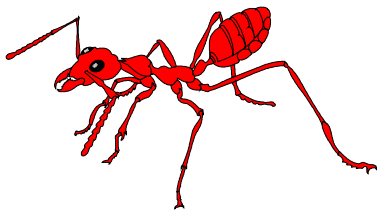
ANTS

Autonomous Negotiating Teams

26 October 1998

Bob Laddaga

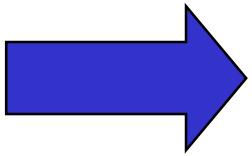
ITO



What if we win the war?

Winning the Information/ Electronic Technology War

- Computing everywhere
- High bandwidth everywhere
- Sensors and effectors everywhere



- Sensor - shooter reactive loops
  (missiles, guns, sensor controls - all computing, connected)

What Then?

Making the New Order Work
(*a few problems*)

- Enormous complexity
  (100K+ computers & devices, interconnected)
- Top down approaches don't scale
  communications fan-in, fan-out
- Pace of change implies that initiative and timeliness are essential but unsupported
  dynamic planning required
- Character/extent of human-to-system interactions.
  Who will live in cyberspace, where everything gets done?

New Approach to System Building: Negotiating instead of Integrating

Problems	Responses
• Enormous complexity • Top down doesn't scale	• Self-organizing systems, & bottom-up organization based on negotiation
• Computing power wasted	• Distributed computation easier with bottom-up organization
• Initiative, Timeliness essential but unsupported	• Bottom-up organization allows timely initiative
• Autonomous operation required by problem scale	• Intelligent ANTs - real-time, satisficing SW entities - based on agents

Program Goal

The goal of ANTs is to autonomously negotiate the assignment and customization of resources, such as weapons (or goods and services), to their consumers, such as moving targets.

Strategy:

- Build ANT technology
  - real-time negotiation, dynamic organization capability
  - ANT runtime software support
- Show application to defense systems
  - demonstrate linear scaling on defense logistics application
  - demonstrate real-time performance and linear scaling in reactive defensive weapon application

ANTS

Program Goal

The goal of ANTs is to autonomously negotiate the assignment and customization of resources, such as weapons, to tasks, such as moving targets.

Applications include: logistics, dynamic planning, and reactive weapon control.

ANT Technology

- **Reasoning based Negotiation**
  - **Real-time response**
  - **Assurance of meeting goals**
  - **Handling, expressing uncertainty**
- **Peer-to-peer and bottom-up organization**
  - **Discovery of peers, tasks and roles**
  - **Access and authorization**
  - **Contribute to plan and task coordination at higher levels**

Key Milestones

1. Negotiation experiment, determine real-time capability
2. Logistics demonstration
3. Dynamic air campaign planning demos
4. Electronic Countermeasures Demonstration

1:4Q00 2:1Q01 3:4Q02 4:4Q03

Example: Bottom-up Logistics

- Every entity has an ant
  (brigade, soldier, rifle, radio, etc)
- Ants negotiate resources, authorizations, capabilities, actions and plans
- Ants bid for open tasks
- Ants bid to supply operations

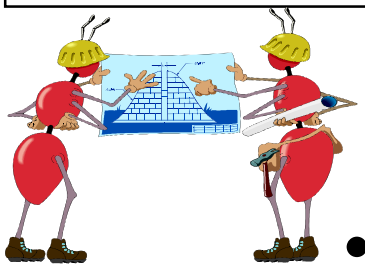
Moving Day Challenge

- Scenario
  - Government of Columbia threatened
  - We want to send 5 thousand US forces to Bogota (at request of Columbian govt) to stabilize situation
- Initiation
  - General Y's ant posts order looking for 5K unit to Bogota for 90 days
  - Various units bid for jobs, begin making option deals on equipment, transportation
  - Transport and equipment suppliers begin bidding for support roles

Operations ants

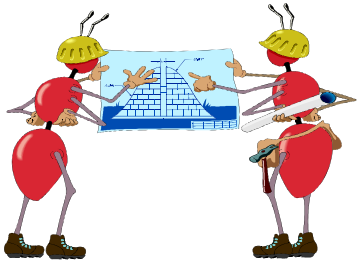
timeline

Mission statement bid for forces:
- goal,
- requirements,
- priority ($)

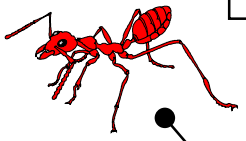


Force ants negotiate site, adversary intel (Mobile Ants go to intel sites, secure planning sites

Equipment vendors ants and transport ants bid for support of operation

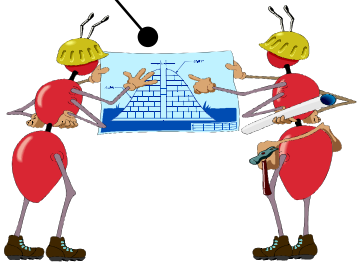


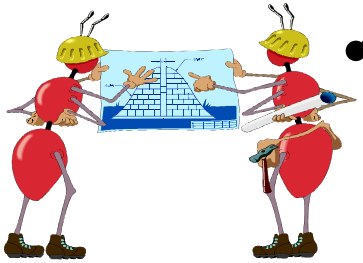
Individual ants state equipment needs



Force ants bid for equipment, transport
- Ants negotiate authorizations, prices, conditions
- Ants go to large data sources

Vendor ants plan, execute supply and transport of equipment





Force ants plan, execute deployment (bottom up deployment of forces, com, s/r)

Defenses on Target

- Many reactive self defense systems are built by DOD:
  - Aegis
  - THAADS
  - Patriot
  - ECM

- Characterized by:
  - closed loop sensor/shooter
  - quick reaction required (secs)
  - many-to-many target match
  - cooperative action required

⇒ **Requires distributed, scalable local action/control with less human interaction**

History: DARPA Moves Aegis to Distributed Computation

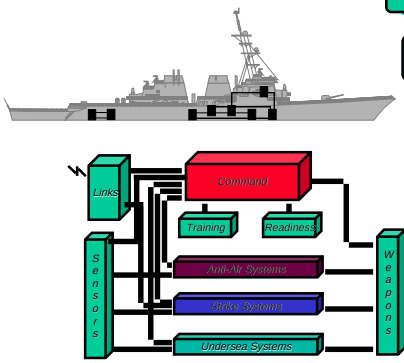
1991-96

HiPer-D

Myrinet

Mach

Isis



Federated

Deployed Today

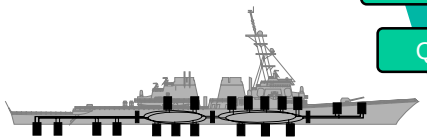
1997-2001

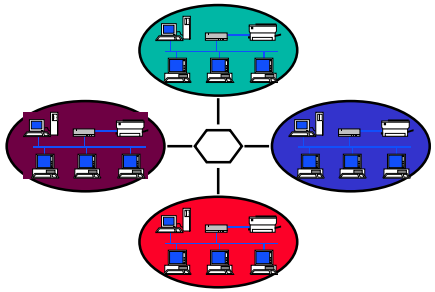
Quorum

Translucent

ARM

QoS

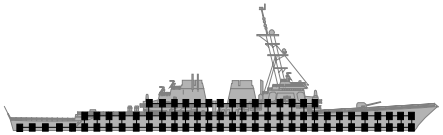


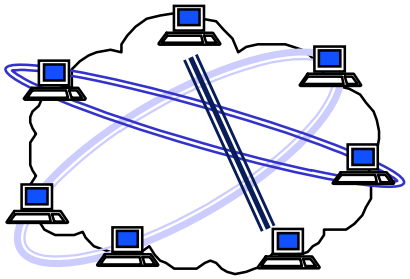


Distributed Proc & LAN

Aegis Baseline 7 (1998)

- Homogeneous COTS
- Network of LANs
- Fixed allocation



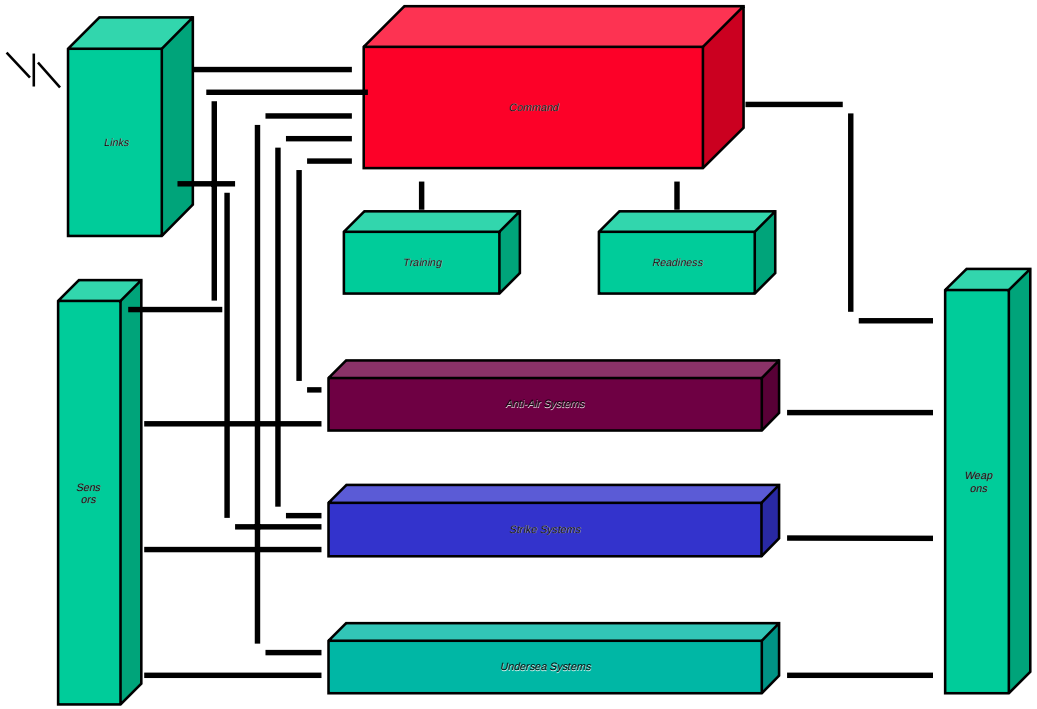


Integrated Computational Plant

DARPA/SC-21 Concept (2010)

- Heterogeneous COTS
- Low latency switched fabric
- Dynamic allocation
- Mixed workload

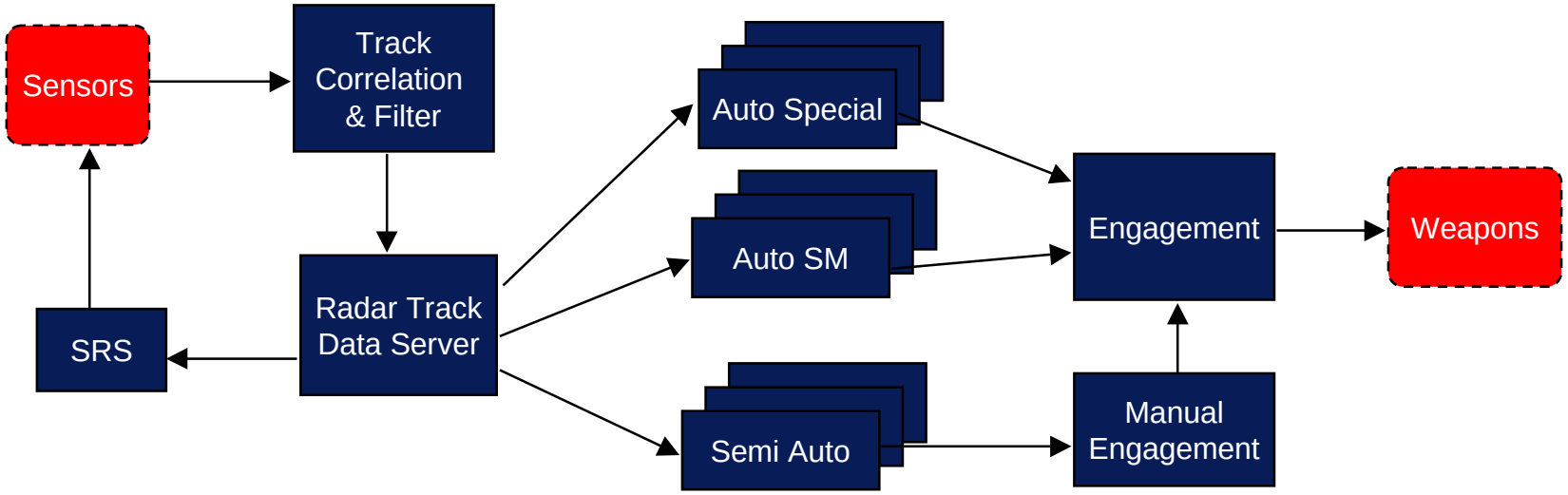
Why haven't we busted the software up?



Federated

Deployed Today

Aegis Information Flow

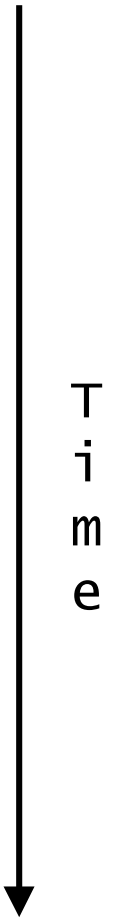


- **Aegis Standard Missile Engagement Path**
- **Demonstrates multiple engagements while processing background tracks**

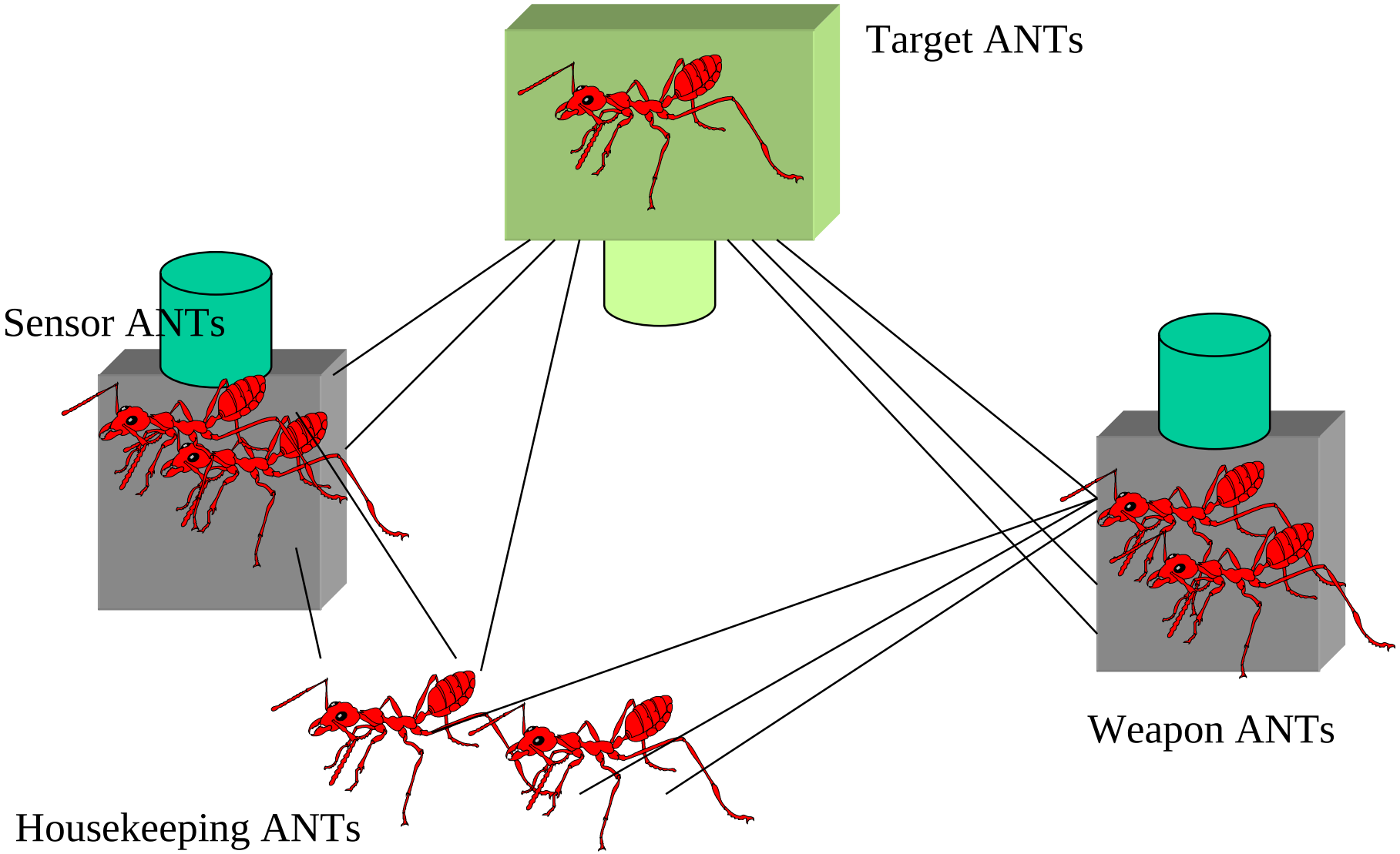
Simulated

Ant Approach to the AEGIS Problem

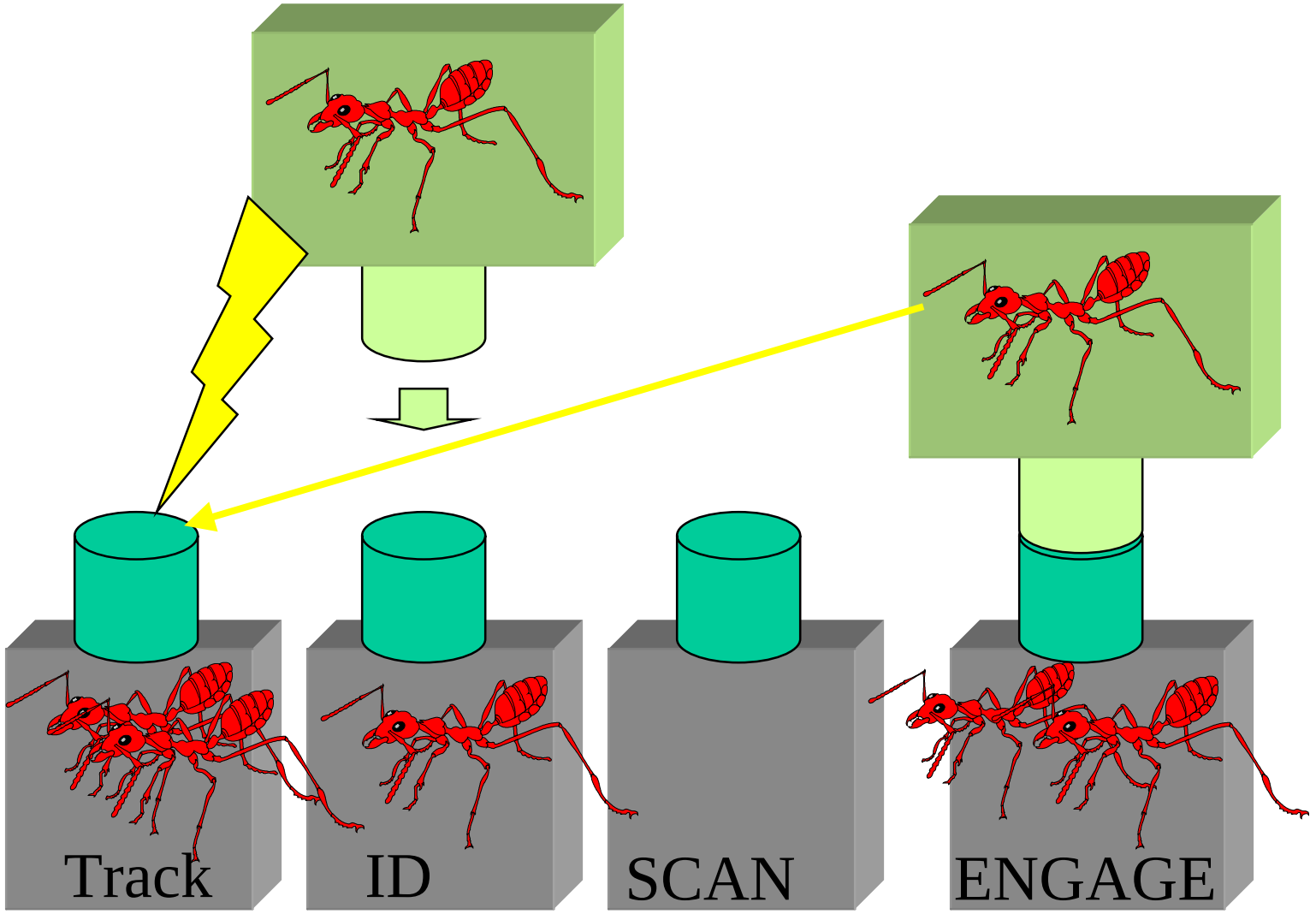
- Threat sighting
  - Ant created when potential threat first sensed
  - Ant negotiates for S/R resources, ID resources
- Threat confirmation
  - Ant negotiates for targeting, elimination
  - Ant visits potential affected parties, seeking destruction commitments, or destruction credits
  - Ant provides all info needed to target and destroy
- Threat Damaged
  - Ant assesses battle damage, repeats as needed
- Ant dissolved



REDANT System Architecture



REDANT Operation



ANT Application Domain

- *dynamic-distributed allocation*
  - *m * n allocation - targets and actors*
  - *m targets (moving changing)*
  - *n actors (moving changing)*
  - *response faster than human time (speed of light delays)*
  - ***good enough & soon enough***
- ***Applications***
  - Reactive defense systems
  - Dynamic replanning (Mission planning - JFACC)
  - Free flight (FAA)
  - Logistics

Why Can't We Do It Now?

- Autonomous and mixed initiative negotiation
  - ant goal awareness, task knowledge, peer discovery
  - structure of ant negotiation
  - resolution of ant conflicts
- Long lived, light weight, mobile ants
- security issues: authorization, secrecy
- representation issues (e.g. policy)
- performance and consistency issues

ANTs versus Agents

- ANTs are punctual
  (operate in “faster than human” time)
- ANTs are light weight
  (good enough, soon enough)
- ANTs coordinate via negotiation
- ANTs are mobile
- ANTs focus on distributed allocation, REDANTs focus on reactive defense

Negotiation in Context

- Many payload to many target problem
  - in general, no closed form solution
  - computational load of decision theoretic approaches too expensive
  - static heuristics trade off too much performance against robustness (and don't achieve a sufficient degree of the latter)
  - negotiation is inherently a dynamic process
  - gradual accumulation and relaxation of constraints

ANT Tasks

- **Negotiation as time and cost effective decision procedure**
  - **Real-time response**
  - **Assurance of meeting goals**
  - Handling, expressing uncertainty, and time/opportunity cost of information and calculation
- **Peer-to-peer and bottom-up organization**
  - Discovery of peer ants, capabilities, tasks and roles
  - Access to and procedures for authorization
  - Contribute to plan and task coordination at higher levels
- Challenge Problems:
  - logistics
  - dynamic planning
  - defensive weapon control (ECM)

Negotiation Questions

- One policy per ANT, or reconfigurable?
- Approach to handling uncertainty
- Continual monitoring of time, progress to good enough solution
- Application specific trade-offs (time vs cost)
- Policy specific trade-offs (e.g. accumulation of contraints before relaxation)

Ant peer-to-peer and bottom-up organization

- Discovery of peer ants, capabilities, tasks and roles
- Access to and procedures for authorization
- Ability to contribute to plan, task and capability coordination at higher levels
- Ability to negotiate tasks, plans and resource needs
- Decision theoretic capability - handling and expressing uncertainty

Organization Questions

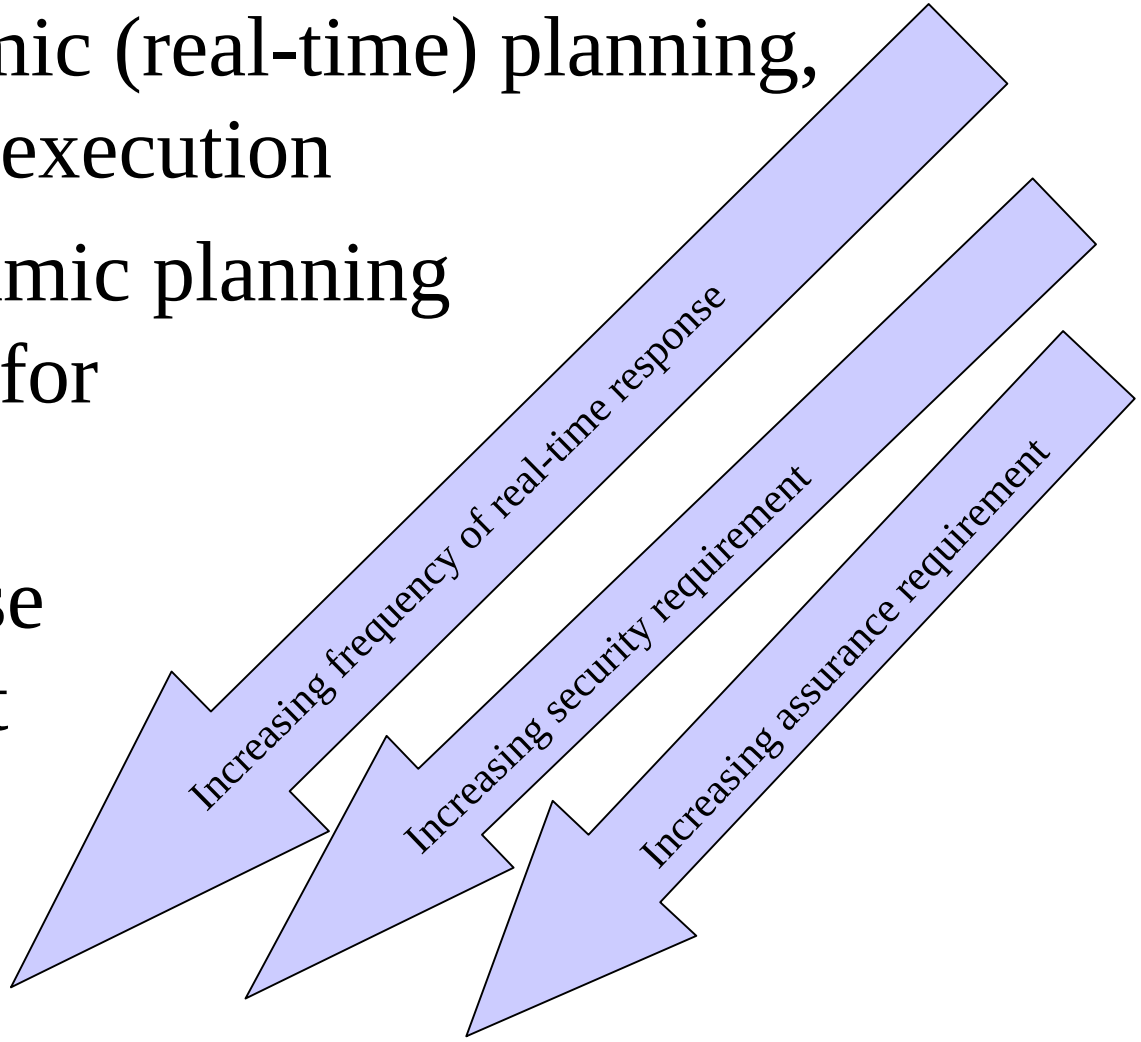
- ANT base
- Need for reconfigurable capability
- ANT generation, destruction, regeneration
- ANT communication requirements
- ANT mobility support
- Application specific requirements

Key Milestones (Experiments& Demonstrations)

- Negotiation experiments
  - handling numerous negotiation policies
  - handling uncertainty, performance requirements
  - providing guarantees
- Challenge problem demonstrations
  - logistics challenge
  - dynamic planning challenge
  - reactive defense challenge

3 Stage Demo Plan for ANTs

- Logistics dynamic (real-time) planning, scheduling and execution
- JFACC++ dynamic planning and scheduling for air campaigns
- Reactive defense ECM in context of UCAV missions



ANTs Logistics Demo

- Build on surrogate agents and real-time monitoring capability
- Add bottom-up initiative based on response to high level goals and on sensor based stores tracking
- Add negotiating capability
- Demo at end of year 2.

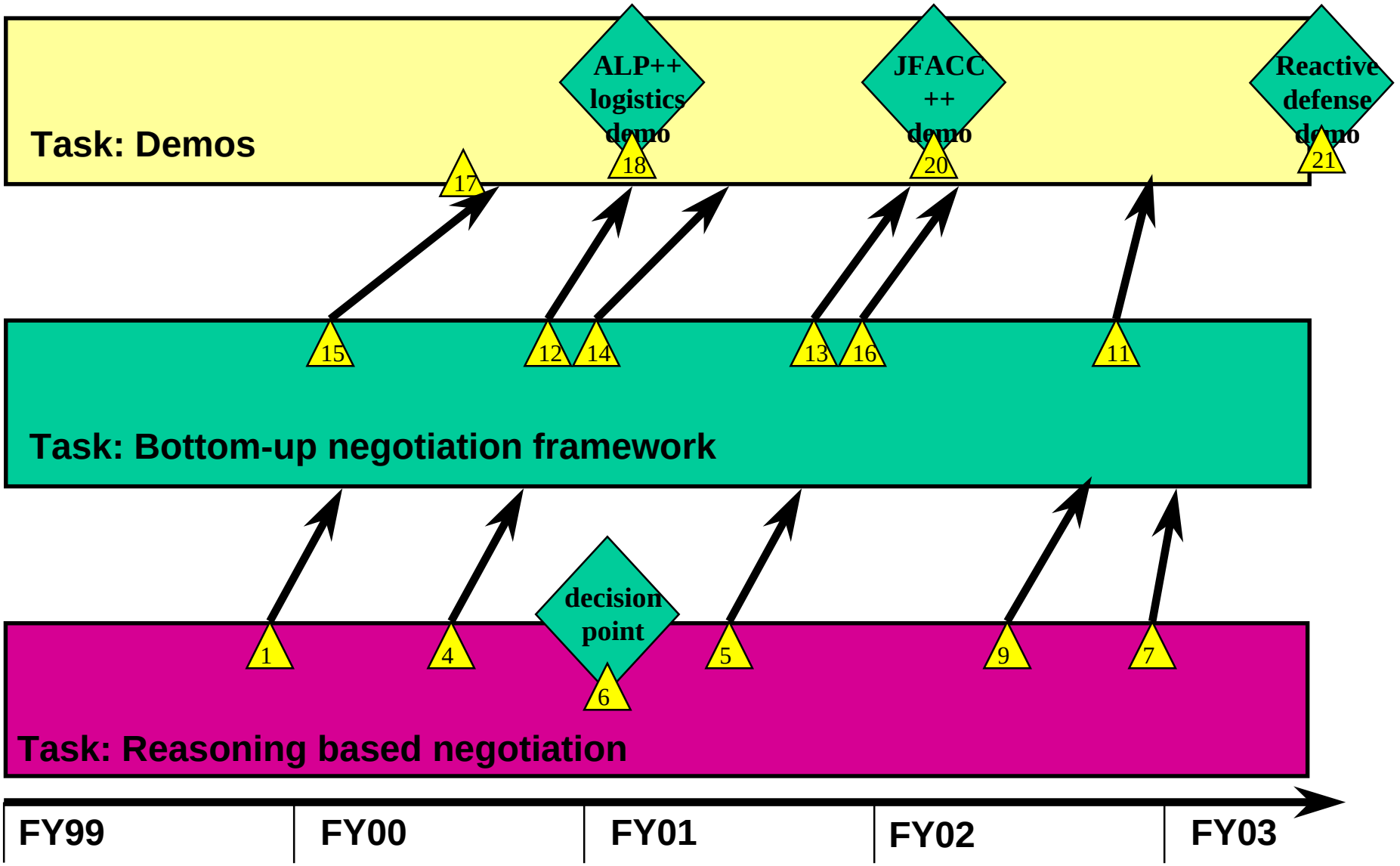
JFACC++ Demo

- Build on logistics real-time ANT substrate and on JFACC dynamic planning capability
- Extend real-time negotiating capability to higher frequency replanning
- Add security requirement to ANT capabilities
- Demo at end of year 3.

Reactive Defense ECM Demo

- Build on JFACC++ real-time ANT substrate
- Apply ANT negotiation to multiple UCAV SEAD mission - highly cooperative, highly reactive
- Extend real-time negotiating capability to extremely high frequency replanning
- Extend security requirement and add high assurance requirement to ANT capabilities
- Capstone demo during year 5.

ANT ROADMAP


Task: Demos
ALP++ logistics demo
JFACC ++ demo
Reactive defense demo
17
18
20
21
15
12
14
13
16
11
Task: Bottom-up negotiation framework
1
4
decision point
6
5
9
7
Task: Reasoning based negotiation
FY99
FY00
FY01
FY02
FY03

Quotes

- "You don't get what you deserve, you get what you negotiate."
  Chester Karras
- "Negotiation is my middle name …"
  ANT